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History of Marine Biology in Virginia, with an Emphasis on Invertebrates

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ABSTRACT

The history of the study of marine biology in Virginia begins with the discovery and exploration of the Chesapeake Bay, the largest estuary in the United States. The Bay was first mapped and explored from 1607 to 1609 by Captain John Smith. At the time it was rich in marine life, including blue crabs, oysters, and clams and its waters were clean and transparent. The ease of water transport made the Bay the heart of early mid-Atlantic settlement. The population of the region had reached 1 million by 1800, but the region was still mostly rural, with Norfolk and Baltimore the major population centers. By the end of that century (1890) the human population had more than doubled, to 2.5 million, the watershed now including large towns and cities (e.g., Washington, D.C.), while new agricultural techniques and crops had led to erosion and nutrient enrichment of Bay waters. Around this time shellfish beds began to decline and a few scientists began to study the effects of human impacts on estuarine organisms and habitats, a process which continues to the present day.

The University of Maryland's Chesapeake Biological Laboratory was founded in 1925 and in 1940, the Virginia Fisheries Laboratory was established in Yorktown, but later moved to Gloucester Point and renamed the Virginia Institute of Marine Science (VIMS). Now part of the College of William and Mary, VIMS students and scientists pioneered studies of the biology of oysters and blue crabs, as well as other benthic organisms and fishes. Additional marine research, particularly in oceanography, takes place at Old Dominion University.

Key words: Chesapeake Bay, marine biology history, Virginia marine and estuarine biology.

INTRODUCTION

This paper is based on a talk given at the Virginia Natural History Society's 2009 symposium on the history of natural history in Virginia. It covers marine invertebrates and general marine biology of the area.

To the earliest explorers "Virginia" meant most of the southeast US coast. Thus, quotations used below may be based on writing by visitors to what are now North Carolina shores, but refer to animals also found in Virginia today. While there are numerous observations on land animals and plants, very few of the early explorers made any reference to marine animals, except those they considered edible or bizarre.

The history of marine biology in Virginia must also be evaluated in terms of the history of biology in the United States and the changing trends in emphasis in biological research world-wide. At the time of European settlement and for most of the Colonial Period biology was part of the great Age of Exploration. European naturalists visiting new regions of the world brought back samples of new life forms, plant and animal, to be described and classified, and where possible, some economic use determined. In the 19th century, exploration of terrestrial and marine diversity continued with the great scientific expeditions, which lasted into the early years of the 20th century, and whose results, in some cases, are still being tallied. Microscopes, invented before the beginning of the 17th century, were improved, allowing the 19th century development of comparative morphology, as well studies of developmental biology, phylogenetics, and genetics, all of which continued to be a focus during the 20th century (Mayr, 1982; Nyhart, 1995; Bowler, 1996).

MARINE AND ESTUARINE HABITATS

The marine and estuarine habitats of Virginia (Fig. 1) include the lower third of the Chesapeake Bay and the tributaries leading into it, the sounds and barrier islands of the open coast, and Virginia's Atlantic coast waters from the intertidal zone to the continental shelf. The Chesapeake Bay is the largest North American estuary. It is formed by the drowned valley of the lower Susquehanna River and developed over 15,000 years' time, and during a 300 foot rise in sea level. The Chesapeake Bay watershed covers 64,000 square miles; the Bay and its tributaries, 150 rivers, streams, and creeks, cover 4,500 square miles and includes 11,700 miles of shoreline (Pritchart & Schubel, 2001; Chesapeake Bay Program, 2009; USGS, 2012). The mainstem of the Bay is almost 200 miles long and holds 18 trillion gallons of water. It ranges in width from four to 30 miles, but its waters are very shallow, averaging only 21 feet deep. Tides are semidiurnal and salinity zones fluctuate, being influenced by rainwater input, currents, and weather conditions as well as the tidal surges.

Salinity in the main part of the lower Bay ranges from 10-18 ppt (mesohaline) to 32 ppt (oceanic salinity) at its mouth. Within the tributaries that enter into the lower Bay, the salinity becomes more and more diluted upstream until the water in the tributary is fresh. Sounds and inlets on Virginia's Eastern Shore have mostly higher salinities than the main Bay due to a smaller amount of fresh water input and less pollution.

Biogeographically, the Chesapeake Bay and the Atlantic beaches and waters from the intertidal zone to the continental shelf belong to the Virginian Province or subprovince. The Virginian marine biogeographic province extends from Cape Cod to Cape Hatteras and is considered a transitional region between cold and warm water marine faunas. Most benthic animals found there have wide distributions. Few species are endemic and the region is considered depauperate compared to the adjoining Atlantic Boreal and Carolinian regions (Briggs, 1974). The reason for this lack of diversity may be partly due to the lack of hard substrata and therefore of epibenthic organisms. It may also be related to wide seasonal variations in bottom temperatures (Franz & Merrill, 1980; Franz et al., 1981).

EARLY EUROPEAN EXPLORATION PERIOD

Captain John Smith, of the Virginia Company, landed near Lynnhaven Inlet, on 26 April 1607 (Williams, 2007). The Company settled in a location farther up the Bay, at Jamestown, on the north side of the James River. During explorations of their new land between late spring 1607 to fall 1609 (Williams, 2007), Smith and some of his men took smaller boats on trips covering most of the Bay and its navigable rivers. At that time Chesapeake Bay waters were clear and clean, with large fields of underwater grasses and vast expanses of oyster beds, making compelling propaganda for Smith to use to entice potential colonists (Wharton, 1973; Ernst, 2003; Williams, 2007; Chesapeake Bay Program, 2009).

The name Chesapeake came from the local Native American name "Chesepiooc", which has been variously translated as at the "great shellfish bay" or "at a big river" or "Great Water". Native Americans living along the mid-Atlantic coast had also given names to some of the larger invertebrates and fish, especially those that were edible. *Seékanauk* was their name for the horseshoe crab (*Limulus polyphemus*). In his *Briefe and True Report of the New Found Land of Virginia...*, Thomas Hariot (1590) wrote that the *Seékanauk* ". . . a kind of crusty shellfish, is a good food. It is about a foot wide, has a crusty tail, many legs, like a crab, and its eyes are set in its back. It can be found in salt-water shallows or on the shore." According to Hariot (1590), there were also "mussels, scallops, periwinkles, and crayfish."

Rare animals got more attention from the explorers than common ones, as did those that looked bizarre, such as the horsehoe crab. They were collected and taken back to Europe, at first as curiosity cabinet treasures, but by the mid-1700s, they were also collected for the purpose of being scientifically described by European scientists. Some, like the horseshoe crab, quahog (*Mercenaria mercenaria*), and soft-shell clam (*Mya arenaria*), were described by Linnaeus (1758). Other Chesapeake Bay species were named only slightly later, e.g., the oyster (*Crassostrea virginica*) by Gmelin (1790), the hydroid *Cordylophora caspia* (Pallas, 1771), and the sponge, *Microciona prolifera* (Ellis & Solander, 1786).

Thomas Hariot (1590: 256) made the first mention of ". . . large and small *oysters*. They are found in both salt and brackish water, and, as in our own country, those taken from salt water are the best." Before the 1800s, oysters and blue crabs, as well as other shellfish, were extremely abundant in the Bay, as European visitors documented in their writings. Englishman William Strachey (1612) wrote "Oysters there be in whole banks and beds . . . some thirteen inches long...." Another visitor, Francis Michel from Switzerland wrote in 1712 that "The abundance of oysters is incredible . . . there are whole banks of them so that the ships must avoid them. I often cut them in two, before I could put them in my mouth" (Michel, 1916).

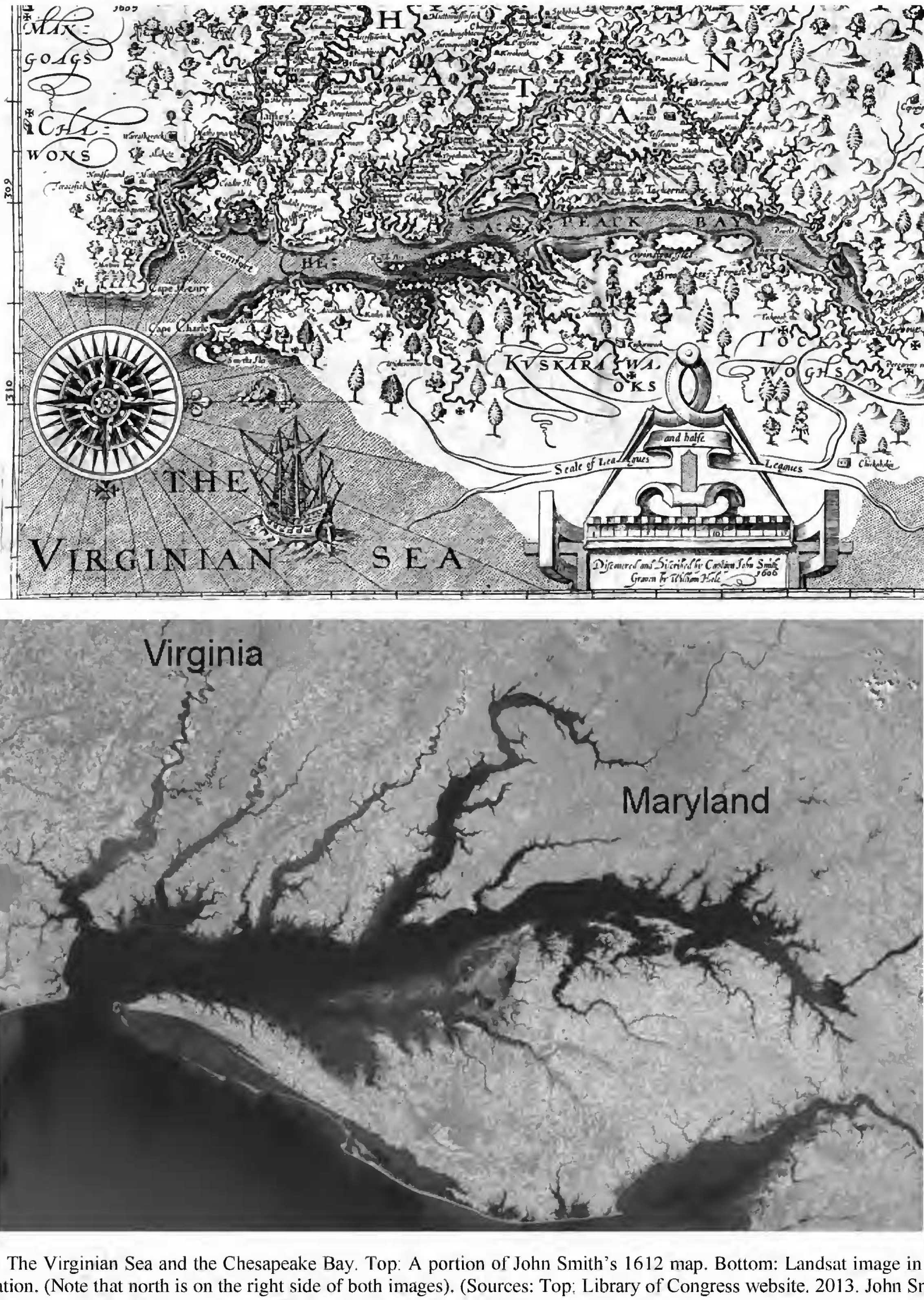


Fig. 1. The Virginian Sea and the Chesapeake Bay. Top: A portion of John Smith's 1612 map. Bottom: Landsat image in same orientation. (Note that north is on the right side of both images). (Sources: Top: Library of Congress website. 2013. John Smith's Map of the Chesapeake Bay. http://www.loc.gov/exhibits/treasures/ images/ s19.2.jpg (accessed 29 April 2013). Bottom: Image of the Chesapeake Bay taken from Landsat satellite data. VA, USA, image taken by US Geological Survey, NASA on 2 October 2009. Used courtesy of the US Geological Survey.)

HISTORY OF RESEARCH ON MARINE INVERTEBRATES FROM 1800

The 19th century marked the development of an American biology, with US scientists establishing research and teaching careers. Some of them had been trained at European universities, others at US institutions by transplanted Europeans such as Louis Agassiz. Most of their research was morphological and taxonomic in nature. Ecology had not yet developed as a separate discipline, although in the latter part of the century it was becoming clear to fishermen and legislators, as well as to scientists, that many of the country's terrestrial and marine resources, so plentiful in the 1600s, were being depleted (Ernst, 2003).

Oysters (Fig. 2)

The life cycle of the oyster is now a staple of life history theory; the "Elm-Oyster Model" describes organisms with a huge lifetime output of millions of sexually produced offspring (Williams, 1975). Consequently, oyster populations in the Bay would seem hard to destroy. Before contact and even for the first 250 years after European settlement this was the case. Native American populations along the Chesapeake Bay were relatively small at the time of European contact, and although shell middens indicate intensive harvesting at some sites, a lack of significant reduction in size of the oysters found in middens indicates that they were not being overharvested (Miller, 2001). In the 1700s, tonging for oysters was common along the Bay. They were at first considered poor people's food, but later a commercial oyster trade with other parts of the colonies developed (Wennersten, 2007).

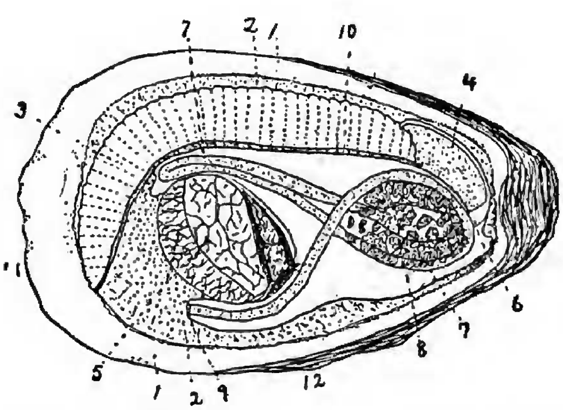


Fig. 2. The American Oyster *Crassostrea virginica.* Fig. 904 of Pratt (1916), a rendering of one of William K. Brooks's illustrations of oyster anatomy, from his reports to the Maryland Shellfish Commission.

In the early 19th century, with the arrival of northern seafood companies to open packing plants, a new way to harvest oysters by dredging was introduced to the Chesapeake Bay. Since dredging left few oysters on the bottom to reproduce and re-seed the population, the use of dredging had already depleted the northeastern oyster grounds around Cape Cod and Long Island. Dredgers headed for the still abundant grounds of the Bay, greatly expanding the oyster business up to the time of the Civil War. After the war, the use of another new technology, steam-canning, made long distance transport of the product possible (Wennersten, 2007).

During the 1870s, there was a great boom in oyster popularity. Oysters were shipped to England and Europe as well as other parts of the US. The competition for oysters led to a series of "oyster wars" between tongers and dredgers and between Maryland and Virginia over a disputed boundary separating the two states along the Potomac River and across the Chesapeake Bay to the Eastern Shore. Overexploitation by the dredgers led to "oyster piracy", forced servitude of immigrant laborers, and violence over the best remaining locations. The violence was controlled by the late 1880s, but oysters remained an extremely popular commodity up until the start of World War I. By the 1890s, the decline in oyster populations, from 15 million bushels harvested in 1884 to 10 million in 1890, had become obvious and initial inventory and conservation efforts had begun. However, they had little effect on the efforts of those involved in the industry to get their share of the dwindling resource (Wennersten, 2007).

The effects of two world wars and the intervening Depression reduced oyster harvesting. In the late 1940s and early 1950s, another oyster war between Virginia and Maryland erupted on the Potomac River, one which was finally settled by legislation in 1962. By that time oysters had other problems, including excess nutrient pollution, siltation, heavy metals, excess freshwater input from storms such as Hurricane Agnes (1972), and lack of adult oysters on which the oyster spat could settle due to removal of adult oysters and attached shell material. In addition to these environmental stressors, three new oyster diseases caused by protistan parasites, MSX, caused by *Haplosporidium nelsoni*, SSO, caused by *Haplosporidium costale*, and "Dermo" caused by *Perkinsus marinus* (Rothschild et al., 1994; Smith et al., 2003; Kemp et al., 2005; Kirby & Miller, 2005). Oyster harvests declined from 125 million pounds in 1880 to 25 million in 1978 and are still decreasing (National Oceanographic and Atmosperic Administration, 2013) (Fig. 3).

There are several new efforts to change this trend. They include rearing oysters to settlement stage, oyster

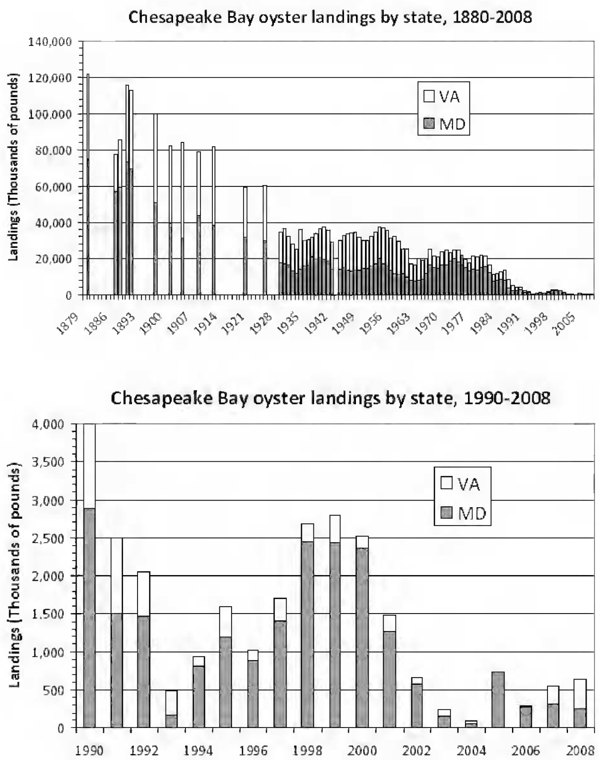


Fig. 3. Chesapeake Bay oyster landings by state, 1880-2008 (top) and 1990-2008 (bottom). Source: National Oceanographic and Atmospheric Administration. Chesapeake Bay Office website. Oysters. http://chesapeakebay.noaa.gov/fish-facts/oysters (accessed 29 April 2013).

aquaculture, and the restoration of hard grounds (e.g., dead oyster shells and other material) in areas where original oyster reefs were destroyed, ideally using areas where oyster banks had originally built up on hard paleo-terraces (Smith et al., 2003; Wennersten, 2007).

Blue Crabs (Fig. 4)

Like oysters, blue crabs (*Callinectes sapidus*) do not recognize the political division of the Bay into Maryland and Virginia portions, which has resulted in disputes over harvesting of those resources. Unlike oysters, blue crabs are mobile. Although male crabs venture farther up the Bay than females at some times of the year, mating takes place in the mid-Bay during summer and fall when the female crabs' shells are soft after molting. Following mating, the females migrate south to the mouth of the Bay, where they spawn and then carry the developing eggs until they mature into larvae. The planktonic larvae molt several times before turning into juvenile crabs that settle to the bottom where they can grow to adulthood in 12-16 months (Lippson & Lippson, 2006).

The blue crab harvest, like that of oysters, has sharply declined (Fig. 5, top) and for many of the same reasons, ranging from habitat loss (especially of the eelgrass beds and oyster bars that served as nursery areas for young crabs), declining water quality, loss of food sources due to benthic pollution and oxygen-deprived dead zones, as well as over-exploitation. In recent years, however, blue crabs have begun to make a comeback, in large part due to a cooperative agreement between Virginia and Maryland that has limited the numbers of female crabs that can be harvested (Pala, 2010; NOAA, 2012). Government fishery statistics for the last few years show blue crab populations finally beginning to increase to a sustainable level (Fig. 5, bottom). The most recent figures show the Chesapeake Bay blue crab population at a 20-year high level (Meola, 2012).

Description of Chesapeake Bay
Marine Invertebrates

Although the first descriptions of marine animals found in the Chesapeake Bay were made by European scientists, by the 1800s American biologists were beginning to publish on their native flora and fauna. The 1972 compilation volume, "A Checklist of the Biota of Lower Chesapeake Bay, with Inclusions from the Upper Bay and the Virginian Sea" (Wass et al., 1972) is based on research at the Virginia Institute of Marine Science and earlier work (including Cowles [1930]), and lists all of the species known at that time. It can be used to document the increase in knowledge of the Bay's invertebrates. Taxonomic description of new species peaked between 1850 and 1899 for most marine invertebrate phyla. Some groups were described before others, for reasons that included size, accessibility (e.g., intertidal vs. dredged), the popularity of the group with collectors, and the regional interests and taxonomic specializations of the marine biologists involved.

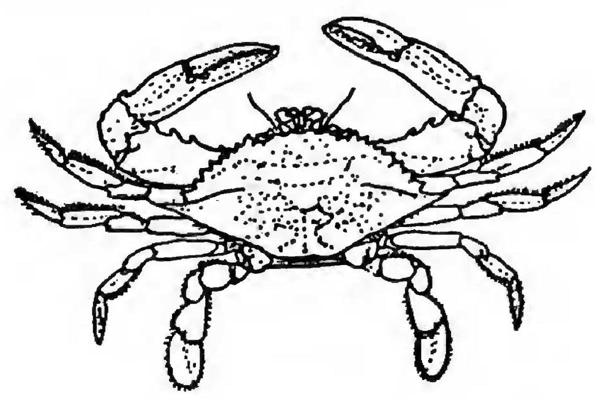
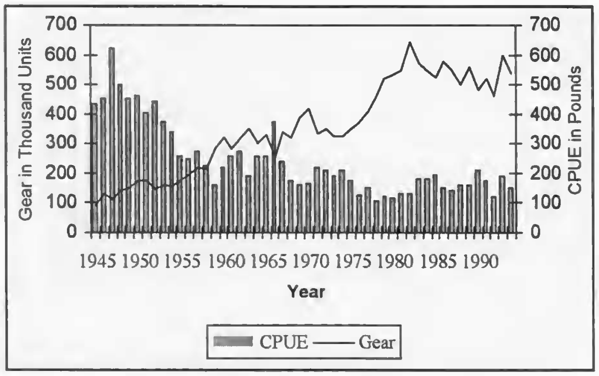


Fig. 4. The Blue Crab *Callinectes sapidus*. Fig. 634 of Pratt (1916).



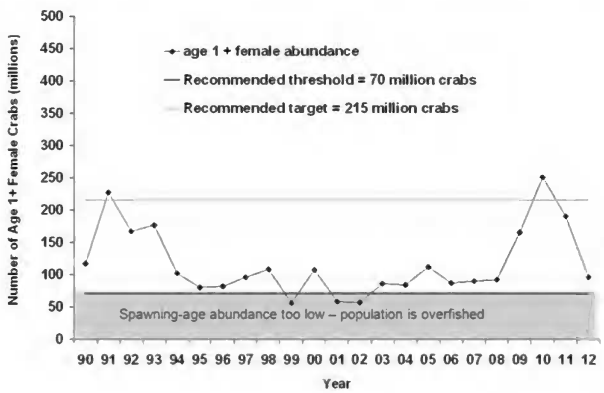


Fig. 5. Top: Fishing effort and catch per unit effort (CPUE) for the Chesapeake Bay Blue Crab Fishery, 1945-1990. Bottom: Abundance estimates of female and juvenile crabs from the annual Winter Dredge Survey 1990-2012. (sources: Top graph: Ernst, 2003, figure 5.2; Bottom graph: NOAA Chesapeake Bay Office, 2013. Blue Crab. http://chesapeakebay.noaa.gov/fish-facts/blue-crab (accessed 30 April 2013).

Table 1 shows the number of new Chesapeake Bay area invertebrate species described in each 50-year time interval in contrast to the cumulative number of species known in those phyla. By 1972, 823 species were known and the accumulation curve was beginning to flatten out, suggesting that most of the species in the Bay had been described by that time.

The same data set (Wass et al., 1972) can be used to document the peak intervals of description of new invertebrate species in different taxonomic groups (Table 2). Greater numbers of mollusks were described early in the time interval, which is not surprising considering their generally large size and the popularity of their shells with collectors. Arthropods followed, but more arthropods were not discovered until the 20th century as compared to mollusks. This probably reflects a later emphasis on the smaller and/or planktonic species of crustaceans, such as copepods and amphipods. Description of the cnidarians (e.g., hydroids, jellyfish, and sea anemones) also peaked during the second half of the 19th century. Annelid worms show a similar late 19th century peak in species descriptions published, but nematodes, which are mostly tiny or parasitic, were almost all described in the 20th century, with the number of new species still increasing in the second half of that century.

Table 1. Total number of Chesapeake Bay invertebrate species scientifically described from before 1750 to 1972 (as documented in Wass et al., 1972).

Time interval	Pre-1750	1750-99	1800-49	1850-99	1900-49	1950-72
Per interval	8	73	190	305	146	101
Cumulative	8	81	271	576	722	823

Table 2. Scientific description of selected groups of Chesapeake Bay invertebrates from before 1750 to 1972 (as documented in Wass et al., 1972).

Time interval	Pre-1750	1750-99	1800-49	1850-99	1900-49	1950-72
Mollusks	5	19	64	29	4	4
Crustaceans	3	20	81	136	166	29
Cnidarians	0	13	13	30	8	0
Annelids	0	7	15	70	13	11
Nematodes	0	0	0	15	39	52

Taxonomic descriptions may provide important information on how species were collected and named, and, by comparison with present day collections, inform us as to whether their distributions have remained stable or changed. For example, Samuel F. Clarke (1882) described the hydroid *Eudendrium carneum*, from Fort Wool, in Hampton, Virginia, the site of a short-lived summer field station belonging to The Johns Hopkins University. Clarke (1882: 137) wrote, "The rocks forming the piers and also the spiles of the old wharf at Fort Wool are coated during June, July and August with immense quantities of these showy colonies that form a miniature forest, extending at low tide as far as the eye can reach." Although this species remains common on the southeastern US coast and Gulf of Mexico, by the 1970s it had apparently disappeared from the lower Chesapeake Bay (Wass et al., 1972).

Twentieth Century Biology

Biology during the 20th century saw increasing professionalization and specialization of biologists into narrower disciplines such as ecology, genetics, cell biology, physiology, oceanography, etc. Early 20th century research in the Bay was focused on surveys. Cowles' (1930) publication on the surveys of the offshore waters of Chesapeake Bay described 250 organisms, but there was little or no coverage of some groups and only generic level identification for others. Taxonomic description of the organisms found in the surveys sometimes took decades after the end of the survey to complete. For example, the echiurid worm *Thallasema hartmani* was collected during a Fishery Service *Fish Hawk* cruise on 23 August 1920, but only described in 1947 (Fisher, 1947).

The Wass compilation shows that new species continued to be described between the 1930s and 1970, but at a much lower overall rate. Of the 68 named species of Cnidaria listed, only 3 were described in that time period. Of course, for groups in which there were one or more taxonomists working in the area, the pattern was different, e.g., six of the 15 named species of turbellarian flatworms were described in the 1930s or 1940s, thanks to the efforts of E. F. Ferguson and E. R. Jones, who were at the College of William and Mary, Norfolk Division, at the time. From the 1970s to today, most of the research focus has been on ecology and the effects of pollution and habitat degradation on the Bay and Atlantic shores, restoration ecology, biological studies of commercially important species like oysters and blue crabs, development of aquaculture, invasive species studies, and oceanographic exploration of the Bay and the offshore waters.

CHESAPEAKE BAY RESEARCH INSTITUTIONS

Academic Institutions

The history of academic institutions carrying out marine and estuarine research in the Bay begins, not with Virginia, but Maryland. The Johns Hopkins University was home to the Louis Agassiz-trained biologist Dr. William K. Brooks from 1873 to 1908. Brooks was very involved with work on the oyster for the Maryland Oyster Commission during the 1880s (see his diagram of oyster anatomy, Fig. 2), but he also founded the Chesapeake Zoological Laboratory to promote the study of marine and estuarine organisms in a summer program. The university did sponsor a summer field station in Virginia at Fort Wool in 1879 and 1880, but later Brooks' summer laboratory was moved to Beaufort, NC, and its scope was broadened to the marine animals of the Atlantic coast (McCullough, 1969).

The University of Maryland's Chesapeake Biological Laboratory was founded in 1925 by Dr. Reginald V. Truitt. It is located at Solomons, Maryland, on the Patuxent River, on the western shore in the middle region of the Bay. It is now an environmental research and graduate education facility of the University of Maryland Center for Environmental Science. Dr. Truitt was director of the Laboratory until his retirement in 1954. He was also director of the Maryland Department of Natural Resources' Department of Research and Education (Wikipedia article on R. V. Truitt, 2012; Chesapeake Biological Laboratory website, 2013). His own career was devoted mostly to research on oysters, but under his direction, a large series of economic, ecological, and taxonomic publications on Bay organisms was produced.

In 1940, College of William and Mary biology professor Dr. Donald W. Davis (Fig. 6) established the Virginia Fisheries Laboratory (VFL) in Yorktown, Virginia. Beginning that year, a master's program in Aquatic Biology at William and Mary trained marine scientists.

The Virginia Fisheries Laboratory was moved to Gloucester Point on the opposite side of the York River in 1950, and renamed the Virginia Institute of Marine Science (VIMS). Initially, it was an independent state institution, but it has been part of the College

Fig. 6. Donald W. Davis, biology professor at the College of William and Mary, who established the Virginia Fisheries Laboratory (now the Virginia Institute of Marine Science) in 1940. Photo courtesy of VIMS.

of William and Mary since 1979. VIMS scientists and students have pioneered studies of the biology of oysters and blue crabs, as well as other benthic organisms and fishes. VIMS blue crab and fish surveys have continued since 1955, and are vital tools for fishery management. Through the College of William and Mary, VIMS has granted more than 700 graduate degrees in marine science since 1968. VIMS is one of the largest marine research centers in the United States, and a leader in sea grass restoration, oyster aquaculture, and hard clam research at its Eastern Shore Laboratory (VIMS website, 2009, 2012).

Old Dominion University (ODU) was founded in 1930 as the "Norfolk Division" of the College of William and Mary. It became an independent college in 1962 and a university in 1969 (Old Dominion University website, 2012, 2013). The strength of Old Dominion's marine science research program is in oceanography, particularly the study of ocean margins and coastal systems research. Researchers at ODU have carried out many studies and surveys of the the lower part of the Bay, the Atlantic ocean off Virginia, and the Mid-Atlantic Bight (Dauer & Alder, 1995) as well as in other regions of the oceans (Brydges, 2000; Old Dominion University website, 2012, 2013).

State and Federal Agencies

Federal management programs in the Bay began after Spencer Fullerton Baird founded the U.S. Bureau of Fisheries in 1871. At that time a decline or disappearance in some of the upper Bay's fisheries (e.g., anadromous shad and herring) had been noticed (Mountford, 2000). The Bureau's early surveys were undertaken by the U.S.S. *Albatross* (limited to deeper waters of the Bay because of its greater draft) and the U.S.S. *Fish Hawk*. Both ships had been built specifically for oceanographic and marine biological research. The *Fish Hawk* was also built as a floating fish hatchery. Both ships were active from the 1880s to the 1920s. Surveys of the Chesapeake Bay and nearby Atlantic Ocean took place under Lewis Radcliffe (1915-17) and were continued by The Johns Hopkins University Zoology Professor Rheinart P. Cowles from 1920-22 (Mountford, 2000). The surveys resulted in the 1930 report on the "Biological Study of the Offshore Waters of Chesapeake Bay" by Cowles, which is still considered a classic work on the ecology and environments of the Bay.

The Smithsonian Environmental Research Center (SERC) is located in Edgewater, Maryland, but its scientists pursue research throughout the Bay as well as comparative studies in sites around the world. It began with a farm property on the Rhode River that was bequeathed to the Smithsonian Institution and now employs 17 resident scientists and a large group of associated scientists, students, and technicians (SERC website, 2012).

Other federal agencies have also played a role in monitoring and restoration of the Bay. In 1965, the U.S. Army Corps of Engineers received $15 million in funding through the Rivers and Harbors Act. They produced a seven-volume report in 1973 on existing conditions, and in 1977, another 12 volumes on future conditions (U.S. Army Corps of Engineers, Baltimore District, 1973). The U.S. Environmental Protection Agency (EPA) has been a major player in restoration efforts of the Bay. In 1976, the EPA was funded to carry out a second comprehensive study, which resulted in a report issued in 1983 (Hartigan, 1983).

Virginia state agencies involved in research and restoration of the Bay include the Virginia Department of Environmental Quality's (DEQ) Coastal Zone Management Program. The Virginia Department of Environmental Quality belongs to a partnership focused on restoration of the Chesapeake Bay and its watershed called the Chesapeake Bay Program along with partner states Maryland and Pennsylvania, the District of Columbia, and the EPA (Chesapeake Bay Program website, 2013). The Virginia DEQ contributes to the program in the areas of environmental monitoring, nutrient source production, and toxics reduction. Virginia's Marine Resources Commission regulates recreational and commercial fishing rules and licensing, and, under the Marine Police, provides enforcement of regulations, oversees boating safety, carries out search and rescue operations, and is responsible for Homeland Security matters.

VIRGINIA'S MARINE AND ESTUARINE ENVIRONMENTS: PRESENT AND FUTURE

Human Population Growth and the Decline of the Bay

Seventeen million people now live in the Bay's watershed (Chesapeake Bay Foundation website, 2011). The "State of the Bay" report on the health of the Chesapeake Bay by the Chesapeake Bay Foundation issued in December, 2010a compared the current health of the Bay, based on thirteen indicators, to its original state when Colonial settlers arrived (100%). Although the State of the Bay index has risen from 23% in 1983, when the first Chesapeake Bay Agreement was signed, to 31% for 2010, it is still listed as impaired by the EPA.

The indicators used are grouped into three general categories. *Pollution*: nitrogen, phosphorus, water clarity, dissolved oxygen, and toxics, *Habitat*: forested buffers, wetlands, underwater grasses, and resource lands, *Fisheries*: rockfish, blue crabs, oysters, and shad. Although the overall score was just 31%, this percentage represented an increase in the scores of eight of the thirteen indicators. Thanks to the 2008 blue crab regulation changes, the blue crab populations increased, underwater sea grass habitat and forested buffers improved, as did some of the physical and chemical indicators (e.g., dissolved oxygen, water clarity), while the amount of toxics decreased. The decline of "dead zone" areas was a good surprise. The most recent report (2012; issued in February 2013) gives a 1% increase to 32%. Some indicators, such as dissolved oxygen levels, had improved, whereas others, including submerged vegetation had decreased (Chesapeake Bay Foundation website, 2013). More improvement will be needed to bring the Bay to a "stable" 50% of its original Contact period condition.

Much has been written about the politics of the efforts to save the Bay's health and resources (e.g., Schubel, 1986; Baliles, 1995; Ernst, 2003; Wennersten, 2007). There is more cooperation between the states and organizations in parts of its huge watershed, and that is a cause for some optimism, but it will take a much stronger willingness to confront the impact of activities to have a significant positive effect on the health of the Bay.

Physical and Biological Factors

Excessive amounts of nitrogen and phosphorus nutrients reaching the waters from urban, residential, and agricultural runoff are still a problem, although water clarity has improved very slightly. Dissolved oxygen has improved, but not enough to prevent many "dead zones" during summer months. The cleanup of part of the Elizabeth River has partially eliminated one of the most toxic areas in Virginia waters. Efforts to restore natural habitats ranging from wetlands and riparian buffers to oyster reef and seagrass meadows continue to be important in improving tributaries and Bay waters.

Introduced Marine Species

Non-indigenous species (NIS) are an increasing problem in coastal regions around the world (Ruiz et al., 2002; Foffonoff et al., 2009). Some introductions may be relatively benign. For example, the Sea Roach isopod, *Ligia exotica*, was introduced to North Carolina in the 1880s, and has spread from there along the Eastern seaboard with no known harmful effects on native organisms (Fofonoff et al., 2009). Other changes in distribution may not actually be invasions, but rather range extensions due to climate change, e.g., the bryozoan *Bugula neritina* did not occur in the Chesapeake Bay at the time of Wass's (1972) checklist. It is now found in the lower Bay (NEMESIS database, and VMNH collections). Some NIS may be aggressive and destructive to native organisms, e.g., the Veined Rapa Whelk (*Rapana venosa*) first seen in 1998, and now established in the Bay and spreading along the southeastern coast (Harding et al., 2011).

Blackfordia virginica, a hydrozoan jellyfish, is thought to be the first ballast water introduction (1904). It was described as a native to Virginia, but is now known as a Black Sea species that has invaded many other regions (Bardi & Marques, 2009; Fofonoff et al., 2009).

Fofonoff et al. (2009) list 170 non-indigenous species inhabiting the Bay. The earliest recorded introductions are for *Carcinus maenas*, the green crab (1874), *Corylophora caspia*, a hydroid (1877), and *Teredo navalis*, a shipworm (1878). Considering the Bay's long history of European settlement, they and others were probably living there for many years before they were scientifically documented.

THE FUTURE OF VIRGINIA'S MARINE ENVIRONMENTS

A large proportion of Virginia's population lives on the Coastal Plain or watersheds (e.g., James, York) that drain into the Chesapeake Bay. Despite more than 50 years of attempts to restore the Bay, our efforts have not yet restored it to even 50% of its original environmental condition. The populations of some important organisms, like the blue crab, are finally improving. The fate of others, like the oyster, are more uncertain. Oyster aquaculture and oyster reef restoration offer hope, but poaching of aquaculture holdings and leases and continuing pollution temper that hope (Chesapeake Bay Foundation, 2010b). If the oysters disappear, other suspension feeders, like the bryozoan *Alcyonidium verrilli* and the sponge *Microciona prolifera*, both very common in the channels of the lower Bay, may take their place ecologically, but not as sources of human food and icons for tourism. In the long run, the future of Virginia's marine environments is up to us.

LITERATURE CITED

Baliles, G. L. 1996. Preserving the Chesapeake Bay: lessons in the political reality of natural resource stewardship. Virginia Museum of Natural History Foundation, Martinsville, VA. Not paginated.

Bardi, J., & A. C. Marques. 2009. The invasive hydrodmedusae *Blackfordia virginica* (May, 1910) (Cnidaria: Blackfordiidae) in southern Brazil, with comments on the taxonomy and distribution of the genus *Blackfordia*. Zootaxa: 2198: 41-50.

Bowler, P. J. 1996. Life's Splendid Drama: Evolutionary Biology and the Reconstruction of Life's Ancestry, 1860-1940. University of Chicago Press, Chicago, IL. 525 pp.

Briggs, J. C. 1974. Marine Zoogeography. McGraw Hill, New York. 475 pp.

Brydges, M. 2000. Old Dominion University: From the Great Depression to the New Millennium, 1930-2000. Old Dominion University, Norfolk, VA. 231 pp.

Chesapeake Bay Program. 2009. Bay History. 11 pp. http://www.chesapeakebay.net/history.htm (accessed 12 June 2009).

Chesapeake Bay Foundation. 2010a. State of the Bay 2010. Chesapeake Bay Foundation, Annapolis, MD. 20 pp. http://www.cbf.org/document.doc?id=596 (accessed 10 April 2012).

Chesapeake Bay Foundation. 2010b. On the Brink: Chesapeake Bay's Oysters: what it will take to bring them back. Chesapeake Bay Foundation Report. http://www.cbf.org/document.doc?id=523 (released 6 July 2010, accessed 25 April 2013)

Chesapeake Biological Laboratory Website. 2013. Chesapeake Biological Laboratory. http://www.umces.edu/cbl

Clarke, S. F. 1882. New and interesting hydroids from Chesapeake Bay. Memoirs of the Boston Society of Natural History 3: 135-144.

Cowles, R. P. 1930. A biological study of the offshore waters of the Chesapeake Bay. Bulletin of the Bureau of Fisheries 46: 277-381.

Dauer, D. M., & R. W. Alden III. 1995. Long-term trends in the macrobenthos and water quality of the lower Chesapeake Bay (1985-1991). Marine Pollution Bulletin 95: 840-850.

Ernst, H. R. 2003. Chesapeake Bay Blues: Science, Politics, and the Struggle to Save the Bay. Rowman & Littlefield Publishers, Inc., Lanham, MD. 205 pp.

Fofonoff, P. W., G. M. Ruiz, A. H. Hines, B. D. Steves, & J. T. Carlton. 2009. Four centuries of biological invasions in tidal waters of the Chesapeake Bay Region. Pp. 479-506 *In* G. Rilov & J. A. Crooks (eds.), Biological Invasions in Marine Ecosystems. Springer, Berlin.

Franz, D. R., & A. S. Merrill. 1980. The origins and determinants of distribution of molluscan faunal groups on the shallow continental shelf of the Northwest Atlantic. Malacologia 19: 209-225.

Franz, D. R., E. K. Worley, & A. S. Merrill. 1981. Distribution patterns of common seastars of the middle Atlantic continental shelf of the Northwest Atlantic (Gulf of Maine to Cape Hatteras). Biological Bulletin 160: 394-418.

Harding, J. M., W. J. Walton, C. M. Trapani, M. G. Frick, & R. Mann. 2011. Sea turtles as potential dispersal vectors for non-indigenous species: the Veined Rapa Whelk as an epibiont of Loggerhead Sea Turtles. Southeastern Naturalist 10: 233-244.

Hartigan, J.P., 1983. Chesapeake Bay Basin Model. Final Report prepared by the Northern Virginia Planning District Commission for the U.S. EPA Chesapeake Bay Program, Annapolis, MD.

Lippson, A. J., & R. L. Lippson. 2006. Life in the Chesapeake Bay. Third Edition. The Johns Hopkins University Press, Baltimore, MD. 324 pp.

Mayr, E. 1982. The Growth of Biological Thought. Harvard University Press, Cambridge, MA. 974 pp.

McCullough, D. M. 1969. W. K. Brooks's role in the history of American biology. Journal of the History of Biology 2: 411-438.

Meola, O. 2012. Chesapeake Bay blue-crab population at 20-year high. Richmond Times Dispatch. April 19. http://www2.timesdispatch.com/news/2012/apr/19/chesapeake-bay-blue-crab-population-20-year-high/ar-1854411/ (accessed 19 April 2012).

Michel, F. L. 1916. Report on the Journey of Francis Louis Michel from Berne, Switzerland to Virginia, October 2, 1701–December 1, 1702. Virginia Magazine of History and Biography 24: 1-43, 113-141.

Miller, H. M. 2001. Living along the "Great Shellfish Bay". Pp. 109-126 *In* P. D. Curtin, G. S. Brush, &

G. W. Fisher (eds.), Discovering the Chesapeake: the History of an Ecosystem. The Johns Hopkins University Press, Baltimore, MD.

Mountford, K. 2000. In-depth knowledge of Bay began with early monitoring efforts. Chesapeake Bay Journal. Dec. 2000, 5 pp. http://www.bayjournal.com/article.cfm?article=2064 (accessed 25 September 2009).

National Oceanographic and Atmospheric Administration. Chesapeake Bay Office. Website. 2013a. Oysters. http://chesapeakebay.noaa.gov/fish-facts/oysters (accessed 29 April 2013).

National Oceanographic and Atmospheric Administration. Chesapeake Bay Office. Website. 2013b. Blue Crab. http://chesapeakebay.noaa.gov/fish-facts/blue-crab (accessed 29 April 2013).

Nyhart, L. K. 1995. Biology Takes Form. University of Chicago Press, Chicago, IL. 414 pp.

Old Dominion University Website 2012. http://sci.odu.edu/oceanography/ (accessed 3 April 2012).

Old Dominion University Website 2013. http://odu.edu (accessed 26 April 2013).

Pala, C. 2010. Chesapeake crabs: engineering a rebound. Science 330: 1474.

Pratt, H. S. 1916. A Manual of the Common Invertebrate Animals. A. C. McClurg & Co., Chicago, IL. 737 pp.

Pritchard, D. W., & J. R. Schubel. 2001. Human influences on the physical characteristics of the Chesapeake Bay. Pp. 60-82 *In* P. D. Curtin, G. S. Brush, & G. W. Fisher (eds.), Discovering the Chesapeake: the History of an Ecosystem. The Johns Hopkins University Press, Baltimore, MD.

Ruiz, G. M., & J. T. Carlton. 2003. Invasive Species: Vectors and Management Strategies. Island Press, Washington, DC. 518 pp.

Schubel, J. R. 1986. The Life & Death of the Chesapeake Bay. University of Maryland Sea Grant College, College Park, MD. 45 pp.

Smith, G. F., E. B. Roach & D. G. Bruce. 2003. The location, composition, and origin of oyster bars in meoshaline Chesapeake Bay. Estuarine, Coastal and Shelf Science 56: 391-409.

Smithsonian Environmental Research Center Website. 2012. About SERC: History. http://www.serc.si.edu/about/history/aspx (accessed 3 April 2012).

Strachey, W. 1612. The historie of Travaile into Virginia Britania, edited by L. B. Wright and V. Freund. The Hakluyt Society, 2nd series. Vol. 103, London [reprint edition 1953]

United States Army Corps of Engineers. Baltimore District. 1973. Chesapeake Bay Existing Conditions Report: Summary. Corps of Engineers, Baltimore, MD. 126 pp.

United States Geological Survey. 2012. The Chesapeake Bay: geologic product of rising sea level. Fact Sheet 102-98, 6 pp. http://pubs.usgs.gov/fs/fs/102-98 (accessed 23 April 2012).

Virginia Institute of Marine Science Website. 2009. A history of marine science in a historical setting. http://vims.edu/about/history/index/php (accessed 18 June 2009).

Wass, M. L. (compiler) et al. 1972. A Checklist of the Biota of Lower Chesapeake Bay, with Inclusions from the Upper Bay and the Virginian Sea. Virginia Institute of Marine Science Special Scientific Report No. 65. 290 pp.

Wennersten, J. R. 2007. The Oyster Wars of Chesapeake Bay. Eastern Branch Press, Washington, DC. 147 pp.

Wharton, J. 1973. The Bounty of the Chesapeake: Fishing in Colonial Virginia. The University Press of Virginia, Charlottesville. 81 pp.

Wikipedia contributors, "R. V. Truitt," Wikipedia, The Free Encyclopedia, 2013. http://en.wikipedia.org/w/index.php?title=R._V._Truitt&oldid=531090240 (accessed 26 April 2013).

Williams, G. C. 1975. Sex and Evolution. Princeton University Press, Princeton, NJ. 200 pp.

Williams, J. P. 2007. Chesapeake: Exploring the Water Trail of Captain John Smith. National Geographic Books, Washington, DC. 192 pp.